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OPTIMIZATION OF CNC TURNING PARAMETERS FOR AL-6061 USING RESPONSE SURFACE METHODOLOGY

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ABSTRACT

As per the present manufacturing scenario, focus of all manufacturing organizations, is to produce good quality product with a minimum cost. CNC turning process is the most common machining process that is used in now days. Present work has been done, to optimize the machining parameters, for material AL 6061 like, depth of cut, feed rate and cutting speed. MINITAB software is used for formulating the matrix and, for the analysis of regression and response surface methodology.

KEYWORDS: CNC Turning Machine, Aluminium 6061, Minitab, Material Removal Rate & Surface Roughness

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Original Article

INTRODUCTION

Machining is the most widely used process for removing the unwanted material for a desired product. In the manufacturing industry, a pure alloy is required for a good quality product and at minimum manufacturing cost. Aluminium alloy 6061, is most widely used alloy, for the machining and manufacturing of a desired dimensions and shapes, aluminium 6061 alloy is preferred because, it is a lightweight metal and having good machining properties, good toughness, mechanical and thermal properties. In this research work, aluminium 6061 is considered for MRR, by varying the various process parameters like depth of cut, cutting speed and feed rate. Lot of researchers are working for finding, an optimized process, for material removal rate [1]. Jasvir Singh et al. experimentally observed, during dry turning process, the development in various machining parameters like feed rate, depth of cut and cutting speed. They performed the machining on aluminium 6061, with CNMG 120408 EN-TM (H20TI) tool. To get regression equation and for optimization of the parameters RSM is used. In the experiment, they found that cutting speed and depth of the cut, gets minimum effect whereas, the feed rate gets the maximum effect on surface roughness [2]. VikasDhiman et al. presented that, the development and growth of any material depends on its machining. In this study, the various process parameters like cutting speed, depth of cut and feed rate were determined for machining on SS202 material, which shows the impact of material removal rate and surface roughness, by using L9 orthogonal array. Taguchi methodology and ANOVA is applied to analyse the effect of various parameters, on the surface roughness and material removal rate, and the experiment was conducted by Standard Orthogonal Array. In the experiment, they found the result of ANOVA (analysis of variance), using MINITAB software that reported that, mathematical model can approximately describe, the factors within the limits [3]. Joshi et al. 2012 performed the experiment CNC Vertical End Milling on aluminium, for Material removal rate. They said that, material removal process is important for producing different component

and difficult shapes. In the end of milling operation, the end mill cutter is used, for the removal of material form work piece. End milling operation is performed, on the basis of three parameters the feed rate, the cutting speed and the depth of cut, along with it, also search the material removal rate by performing a standard orthogonal array, using Taguchi method. In the experiment, they found the result of ANOVA (analysis of variance) reported that, mathematical model can approximately describe the factors, within the limits [4]. Yadav et al. 2012 reported, surface roughness of Medium Carbon Steel AISI 1045, on turning in dry condition. In this experiment, investigated increment of machining parameters like spindle speed, depth of cut and feed rate for the Ra (surface roughness). In the experiment, the result will be found by an L27 orthogonal array, S/N (Signal to noise) and by the ANOVA (analysis of variance). The result shows that, the most significant factors which affect the surface roughness, is feed rate which is followed by depth of cut were as, the cutting speed is the least affecting factor [5]. Amity Joshi et al. 2013 studied that; the material removal process will be the most affected factor, on manufacturing the product. CNC's End Milling is the most broadly utilized technique, for machining process and the material is removed, by the cutting tool to get desired shape and design. In the experiment work, on the three basic parameters, like cutting speed, feed rate, depth of cut and use of Taguchi method, is used to find the impact on the surface finish. Analysis of variance is used, with a standard orthogonal array that shows that most significant factor is feed rate of surface finish [6]. Hemantsinh Pratapsinh Rao et al., studied the impact of depth of cut, feed rate and cutting speed on MRR (material removal rate) and Ra (surface roughness), using aluminium 6061 alloy through the Taguchi methodology. The result shows that, the cutting speed has a greater impact on Ra (surface roughness) and material removal rate (MRR), which is followed by the depth of cut [7]. Abhishek Kumbhar et al. reported the optimization of machining parameter. They also investigated, the feed rate cutting speed and depth of cut, for material removal rate and surface roughness, on SS304 using end milling machine and they also investigate, the grey relational analysis with the Taguchi methodology [8]. Himanshu Sonar et al. investigated the suitable parameters for machining, for surface roughness and material removal rate. In this experiment, he studied and carried out the parameters like cutting speed, depth of cut and feed rate for aluminium material, in CNC turning machine. Three machining tool are used, for material removing and for surface finish using L9 orthogonal array, in Taguchi methodology. Aluminium alloy 6061 experiment result will be carried out, in Microsoft excel used for regression investigation. The results show that, the machining parameters are acceptable [9].

The above literature survey shows that, the various parameters like cutting speed, depth of cut and feed rate affect the result and varying different, result in different parameter's value.

EXPERIMENTAL SETUP

CNC turning center is the most used machining process, for the accuracy and for high quality products. CNC turning center, is a machining process that is used for the removal of undesirable material from the work-piece, to give the material a desired shape and size. In this experimental setup, Aluminium 6061 is used for machining. In the experiment, minimum surface roughness and the higher material removal rate is required, for the estimation of low cost product. Optimized process for high quality product which are cost effective, is calculated by using response surface methodology, by varying the various parameters discussed below in table1: -

Table 1: Process Parameters and Limits

Machining Parameters	Lower Limit	Upper Limit
Feed rate (mm/min)	78	102
Cutting speed (rpm)	1200	1800

Depth of cut (mm)	0.4	0.6

Below is an Adopted Procedure Followed for Experiment

- Cut the aluminium alloy 6061 by power saw, to the desired dimensions (100 mm length).
- Measured the weight of each sample, by using highly accurate digital weighing machine before machining.
- Prepared the CNC turning code and then performed turning operation, on each sample by varying the cutting speed, the feed rate and the depth of cut.
- After machining, measured the weight of each sample using digital weighing machine.
- Calculated the MRR as: -
- MRR= (initial weight – final weight) ÷ (density × time)
- Measured the surface roughness with the help of a portable stylus type Profilometer “Talysurf”.
- Using MINITAB software, RSM statics was analysed.
- A matrix was formulated, for the experimentation is shown in the below table 2

Table 2: Matrix Formulation for Experiment

Std Order	Run Order	Cutting Speed(rpm)	Feed rate (mm/min)	Depth of cut (mm)
4	1	1800.00	102.000	0.400000
14	2	1500.00	90.000	0.668179
16	3	1500.00	90.000	0.500000
13	4	1500.00	90.000	0.331821
3	5	1200.00	102.000	0.400000
19	6	1500.00	90.000	0.500000
15	7	1500.00	90.000	0.500000
7	8	1200.00	102.000	0.600000
10	9	2004.54	90.000	0.500000
11	10	1500.00	69.818	0.500000
17	11	1500.00	90.000	0.500000
12	12	1500.00	110.182	0.500000
6	13	1800.00	78.000	0.600000
8	14	1800.00	102.000	0.600000
2	15	1800.00	78.000	0.400000
20	16	1500.00	90.000	0.500000
1	17	1200.00	78.000	0.400000
18	18	1500.00	90.000	0.500000
9	19	995.46	90.000	0.500000
5	20	1200.00	78.000	0.600000

RESULT AND ANALYSIS

Following results have been found after the experiment, that shows in the below table 3

Table 3: Experiment Result Data

Sl. No.	Cutting Speed (rpm)	Feed Rate (mm/min)	Depth of Cut (mm)	Initial Weight (g)	Final Weight (g)	Time (sec.)	MRR (mm^3/sec)	Ra (µm)
1	1800	102	0.4	137.87	133.36	38	43.9	1.045
2	1500	90	0.668179	136.06	129.97	40.78	55.3	0.4155
3	1500	90	0.5	136.33	131.55	40.23	44	0.4355
4	1500	90	0.331821	138.74	134.96	41.48	33.75	0.5615
5	1200	102	0.4	137.16	133.09	37.16	40.56	0.498
6	1500	90	0.5	137.27	132.44	39.99	44.73	0.558
7	1500	90	0.5	137.32	132.34	40.43	45.62	0.369
8	1200	102	0.6	136.98	131.3	35.15	59.84	0.471
9	2004.54	90	0.5	135.81	130.95	40.18	44.79	0.3975
10	1500	69.818	0.5	135.02	130	51.51	36.09	0.3785
11	1500	90	0.5	135.97	131.91	40.17	37.43	0.4055
12	1500	110.182	0.5	137.53	132.28	33.19	58.58	0.509
13	1800	78	0.6	137.77	131.88	46.8	46.61	0.373
14	1800	102	0.6	137.97	131.88	35.88	62.86	0.432
15	1800	78	0.4	136.89	132.5	46.48	34.98	0.379
16	1500	90	0.5	140.4	135.01	39.97	49.94	0.3995
17	1200	78	0.4	136.99	132.43	45.81	36.86	0.3665
18	1500	90	0.5	136.88	131.45	40.43	49.74	0.421
19	995.46	90	0.5	136.66	131.2	40.68	49.71	0.5305
20	1200	78	0.6	136.17	130.16	46.03	48.35	0.385

MRR and Ra have been calculated with respect to the experimental data in table 3

RSM Statics for MRR

In the beginning checked the data by the residual plots (figure 1), this plots shows the normality of experiment. The data points as shown in the graph are distributed near and along the normal line, so we called that an normal distributed result. The second plot doesn't shows any interactions between when plotting residual versus fitted value data that shows RSM model is good with the data set. Third plot residual histogram showing data distribution and last graph shows the experiment order of the data points which concerned order significance and not.

Main Effect Plot for MRR

This graph (figure 2) shows the parameters (feed rate, cutting speed and depth of cut) and effect on material removal rate, in case of cutting speed increase, when value is 1550 to 1800 rpm. At the point of 1000 to 1500 rpm, there is a sudden decrease, in the MRR. After that, increasing the cutting speed shows the increase in MRR. In case, of feed rate material removal rate is increasing continuously in all levels of feed rate. Similarly in case of depth of cut material removal rate is increasing continuously up to the 0.66mm, after that the MRR value is increasing slightly.

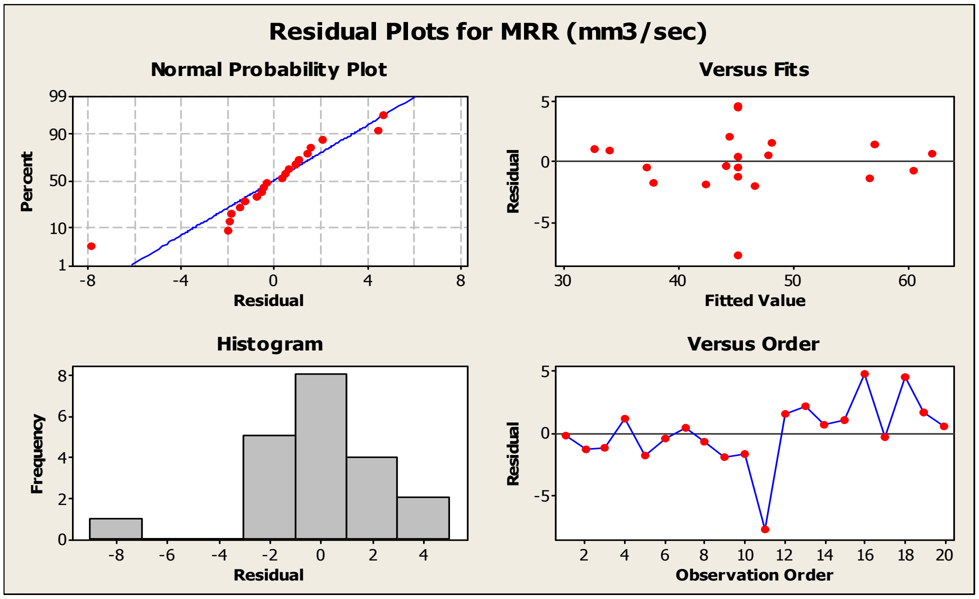

Figure 1: Probability Plot Graph for MRR

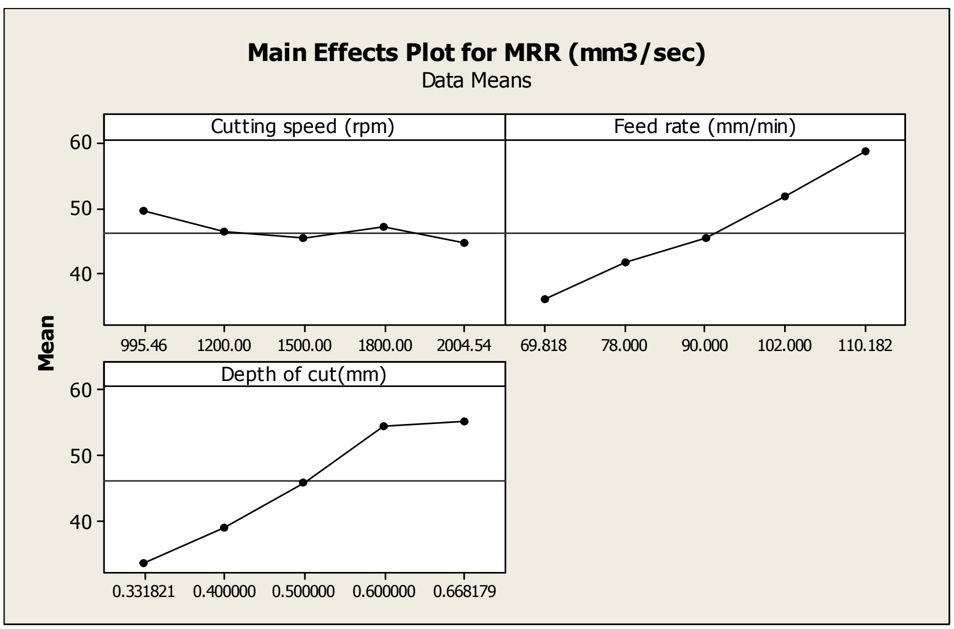

Figure 2: Main Effect Plot for MRR

Graphical Inference of MRR

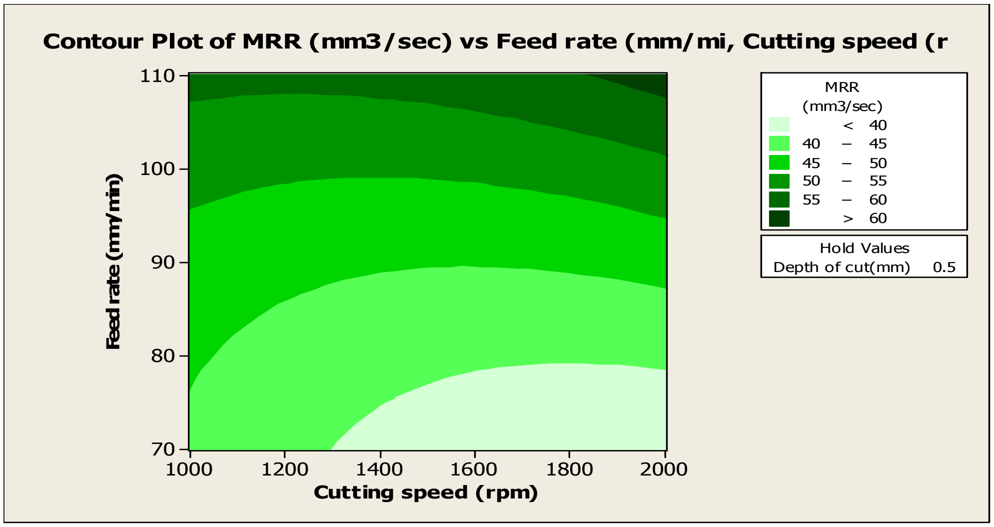

Figure 3: Contour Plot of MRR vs Feed Rate, Cutting Speed

Contour plots are shows the different colour regions on different output values. In this graph (Figure 3) dark green area shows, the cut of feed rate and depth of cut where, MRR value is maximum and above 60 mm^3/sec.

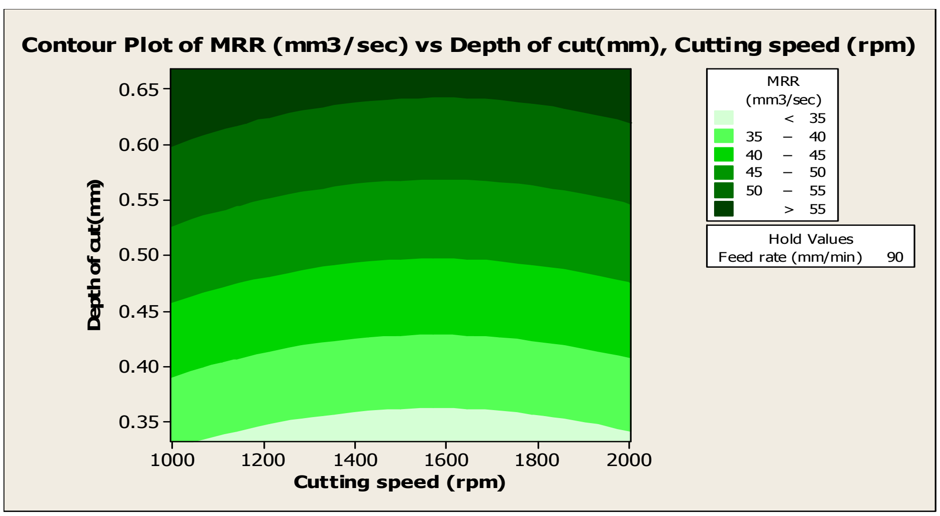

Figure 4: Contour Plot of MRR vs Depth of Cut, Cutting Speed

In the above graph (figure 4) shows the effect of cutting speed and depth of cut on Material removal rate. In the graph all the cutting speed parameters are effective when depth of cut is above the 0.60mm. When cutting speed 1500-1700 rpm and depth of cut is 0.64 mm then the material removal rate is maximum above the 55%.

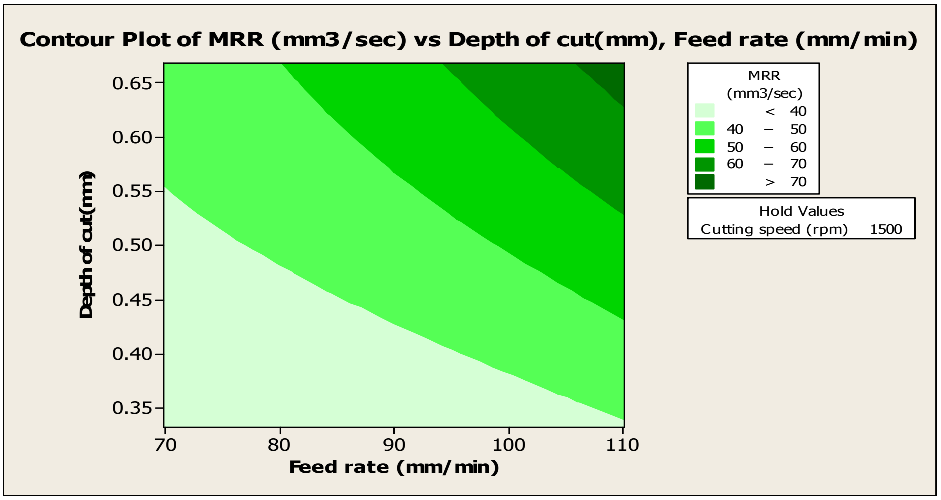

Figure 5: Contour Plot of MRR vs Depth of Cut, Feed Rate

This graph (figure 5) shows relation between depth of cut and feed rate. According to this graph material removal rate is >70% when the depth of cut is about to 0.64-0.66 mm and feed rate is maximum at 108-110mm/min at the hold cutting speed value 1500rpm.

RSM Statics for Ra

For minimizing surface roughness, we performed response surface methodology, using Minitab on input datas. Profilometer is used, for measuring the surface roughness. In this graph (figure 6), shows the normal probability distribution function and it shows parameters that are correct, for performing the experiment. First, normal probability plot shows, all the data point near and along, with the center line that shows the normally distribution. Second, versus fits plot does not interact with any point, shows the plotted data value is correct. Third, the histogram shows, the variation on all the parameters. Forth, observation order all data point, varying in between the line and doesn't show any interaction between any points. All the points show that, our parameters are good for the experiment.

Main Effect Plot

Figure 7, shows the parameter with efficiency of cutting speed, depth of cut and feed rate. Cutting speed shows, when speed is between 995.46-1200 rpm there is a decrease in surface roughness, when speed is 1200-1500 rpm there is a slight increase and when the cutting speed is between 1500-1800 rpm, there is maximum increase, in surface roughness. In the other words, surface roughness increases when the feed rate is between, 78-102 mm/min, in the other side, surface roughness is increasing when depth of cut is between the 0.33-0.40 mm.

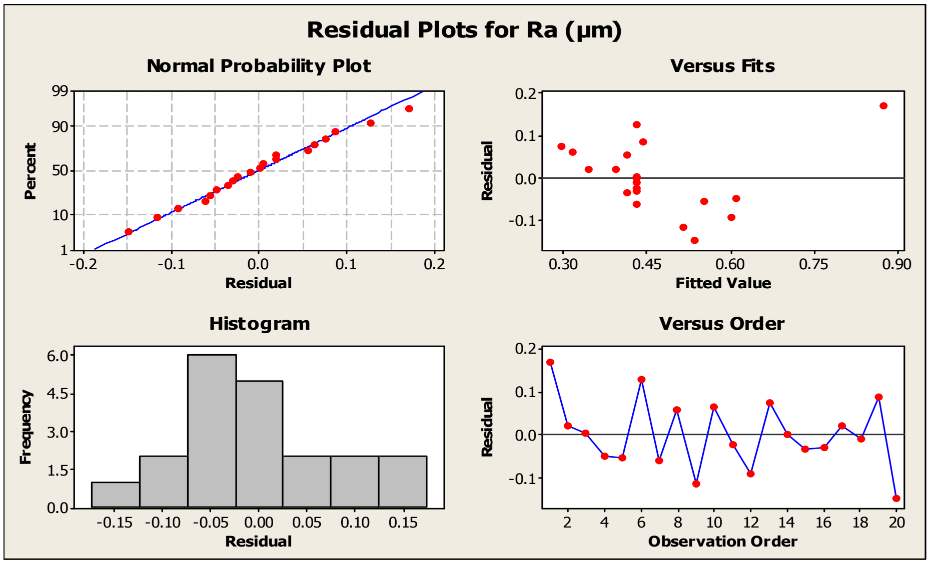

Figure 6: Residual Plot for Ra

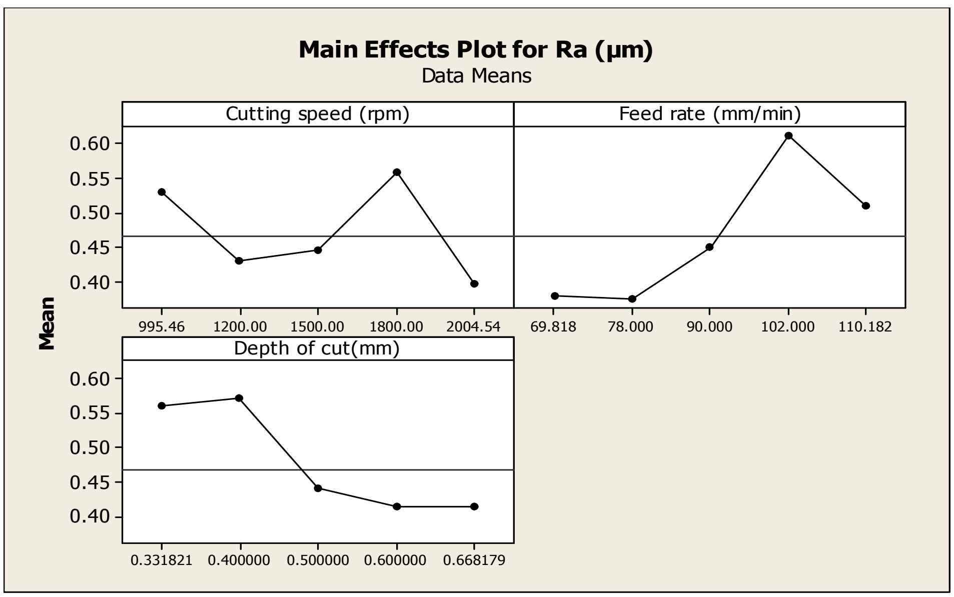

Figure 7: Main Effect Plot for Ra

Graphical Inference of Ra

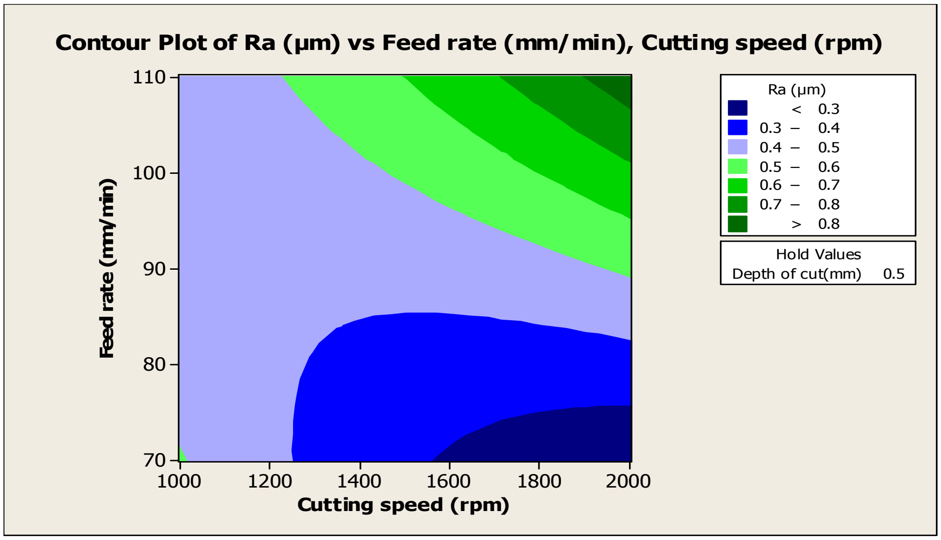

Figure 8: Contour Pot of Ra vs Feed Rate, Cutting Speed

The above graph (figure 8) shows the effect on feed rate and cutting speed, on surface roughness. The graph shows that, surface roughness is minimum (<0.3µm) when cutting speed is maximum (1600-2000rpm) and feed rate is minimum (70-75 mm).

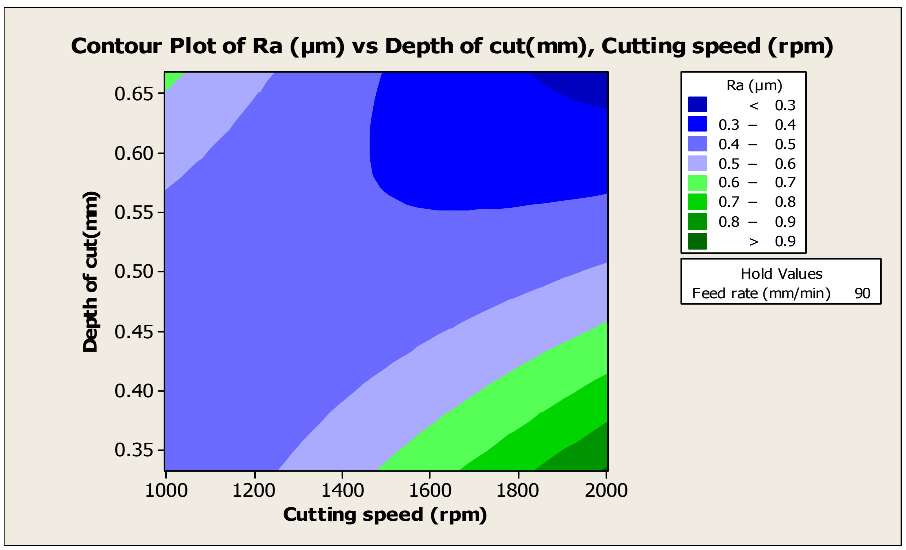

Figure 9: Contour Plot of Ra vs Depth of Cut, Cutting Speed

The above graph (figure 9), shows the response on depth of cut and cutting speed, on the surface roughness. The graph shows that, surface roughness is minimum (<0.3µm) when cutting speed is maximum (1900-2000 rpm) and depth of cut is maximum (0.63-0.66 mm/min).

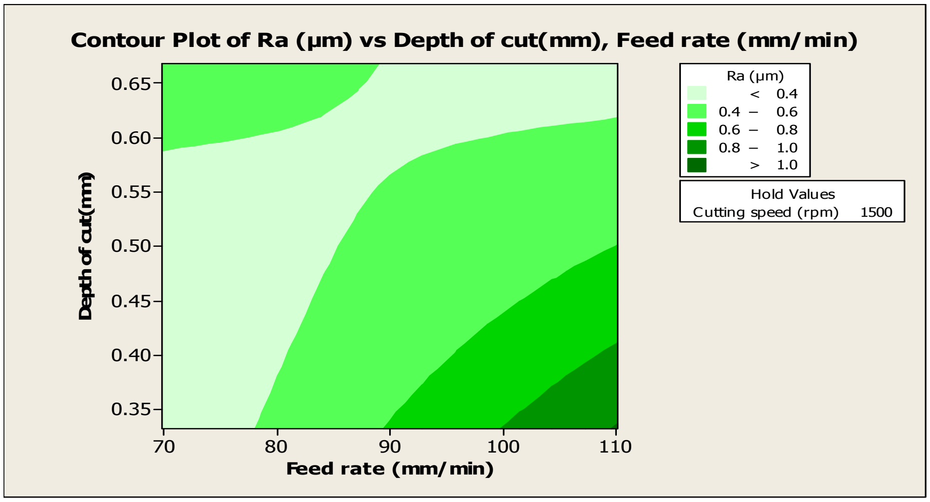

Figure 10: Contour Plot of Ra vs Depth of Cut, Feed Rate

Graph (figure 10), shows the response on depth of cut and feed rate, on surface roughness. The graph shows that, surface roughness is maximum (>1µm) when feed rate is maximum (100-110 mm/min) and depth of cut is minimum (0.35-0.43) mm.

PREDICTED RESPONSE

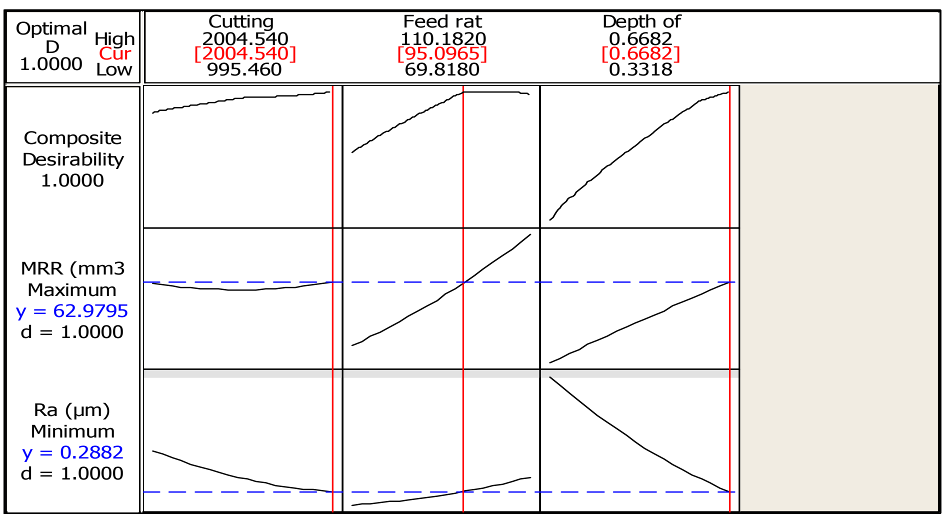

Figure 11: Predicated Responses

CONCLUSIONS

From the predicted response, it has been found that, if the machine is run at the setting of cutting speed, 2004.54 rpm, feed rate of 95.0965 mm/min and depth of cut to be 0.6682mm, then there is 100% composite desirability that we will get, on Material removal rate (MRR) of 62.9795 mm^3/sec and surface roughness (Ra) of 0.2882.

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